Proton Plan
MI Radiation Issues and Collimation
Directors Review
August 2005

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MI Radiation Issues and Collimation

Topics to Be Discussed:

- MI Radiation Levels and Trends
- MI Radiation Monitoring Program
  - Residual Radiation and Monitoring Automation
  - Loss Monitor Status and Upgrades
- MI Collimation Prospects and Plans
  - Loss Issues
  - Lattice Overview
  - Loss Study and Simulation Plans
- MI8 Collimation
  - Specification
  - Design and Implementation Plans
- Risk Assessment, Schedule, Costs

MI Radiation Issues and Collimation

- The Main Injector was sited at a depth which provides adequate shielding so **environmental issues do not normally arise**.
  - Exception: MI Abort is authorized for limited use.
- However, all components are designed for hands-on maintenance. **Residual radiation must be kept to levels which permit maintenance**.
  - We interpret this to mean less than 100 mr at 1 foot.
  - Unlike the Booster RF, there are no MI components (rf, instrumentation) which are predicted to need maintenance and have radiation-inducing aperture limitations. **Where will residual radiation define limits?**
- Radiation damage to components may be a separate issue. We expect to operate the machine such that the residual radiation will be limiting. [Do not dump beam in magnets!]

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Tunnel Residual Radiation Monitoring:

- **Diagnostic Measurements** – all sides of beam pipe at locations which show significant radiation
  - Carried out in June-August 2004 and as possible in 2005
  - Few mr exposure per survey in 2004, 20-30 mr in 2005
  - 2005 surveys incomplete (limited by time and exposure)
  - Comparison of top *vs.* bottom or inside *vs.* outside diagnostic of machine problems
- **Monitoring** – periodic measurements at 'significant' locations around MI Ring.
  - Manually with LSM through July 2005
  - **Bar codes installed, logging meter purchased to monitor about 125 points**
  - Database and data transfer efforts still needed
- Robot would be helpful – more complete, less exposure.

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Residual Radiation measurement have been recorded and reviewed.

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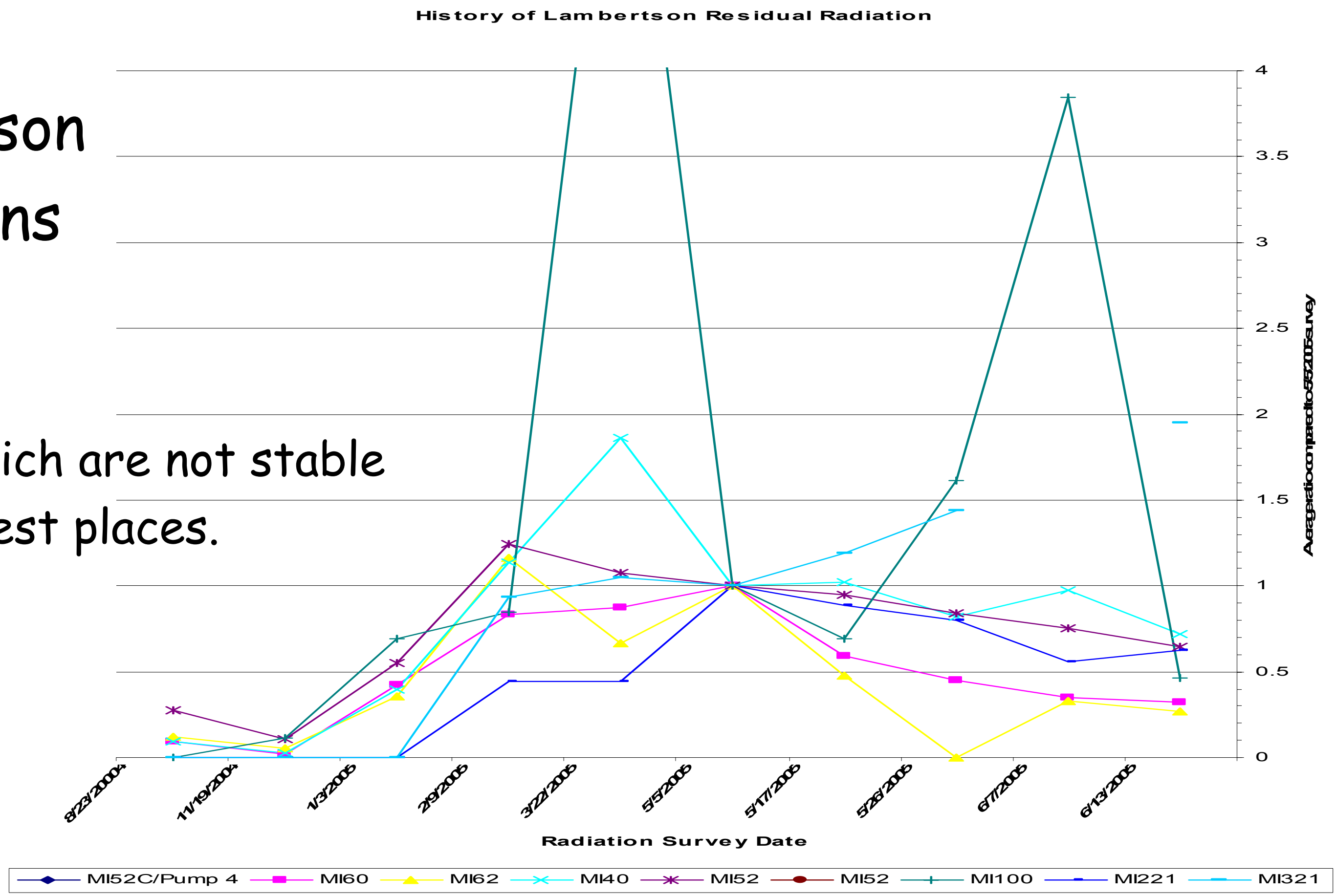
Radiation trends have been monitored at locations with significant radiation



Lambertson Locations

Locations which are not stable are not hottest places.

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We must limit the number of hot locations if we hope to understand existing or new loss sources.

Issues noted:

- Vertical problem at D-Quad Minitubes (tails)
- Radial Problem at F-Quad downstream (longitudinal)
- Lambertsons
- Blunders (alignment, BPM errors)

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MI Loss Monitors

- Adequate number of Tevatron-style Loss Monitors
- Old Electronics is not adequate
  - Cannot report integrated losses but from a few locations. It is adequate for many studies but not suitable for most long term monitoring needs.
- New electronics is being developed which will provide much better real time and logging capability. It should be available in FY06.

Expect to predict residual radiation based on losses (As in Booster). If some losses are not seen by existing LM's we can supplement them with coaxial 'Total Loss Monitors' for some areas.

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What do we know about Main Injector Losses?

- Losses at Injection
- 8 GeV Lifetime
- Slip-stacking Losses – beam lost from design buckets
  - Recaptured in undesired buckets (lost at inj or ext)
  - Uncaptured beam (DC Beam lost on acceleration)
- Losses at MI Transition
- Losses during extraction/transfer

Each of these loss sources has a distinctive pattern for creating residual radiation

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The Main Injector Lattice has no collimation locations in the design. Features include:

- Regular Cells
  - Only Mini-straight sections
  - Moderate dispersion
- Dispersion suppressor cells
  - No straight section space
- Straight section cells
  - Design dispersion is zero
  - All have dedicated use – transfer, instrumentation, rf

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MI Collimation Possibilities

Straight section uses:

- MI52, MI62 Transfer to Tevatron - radial
- MI40 Abort – radial
- MI 10 Injection – vertical plus instrumentation
- MI60 RF, Instr, NuMI Transfer – radial
- MI22, MI32 Radial Transfer to RR
- MI30 Mostly used for electron cooling

Currently we are considering creating some vertical collimation at MI22 or MI32 and radial at MI30

No location with dispersion has been identified.

First proposed lattice change – Beams-doc-1930

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MI Loss and Collimation Study

- Nikolai Mokhov and colleagues will carry out a study of apertures and loss mechanisms in the Main Injector with the goal of prescribing a suitable set of collimators to localize beam lost do to various identified mechanisms
- We speculate that significant lattice modifications will be required to create a section with dispersion where collimation can be placed if we wish to remove unaccelerated beam with collimation.

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MI8 Collimation Plan

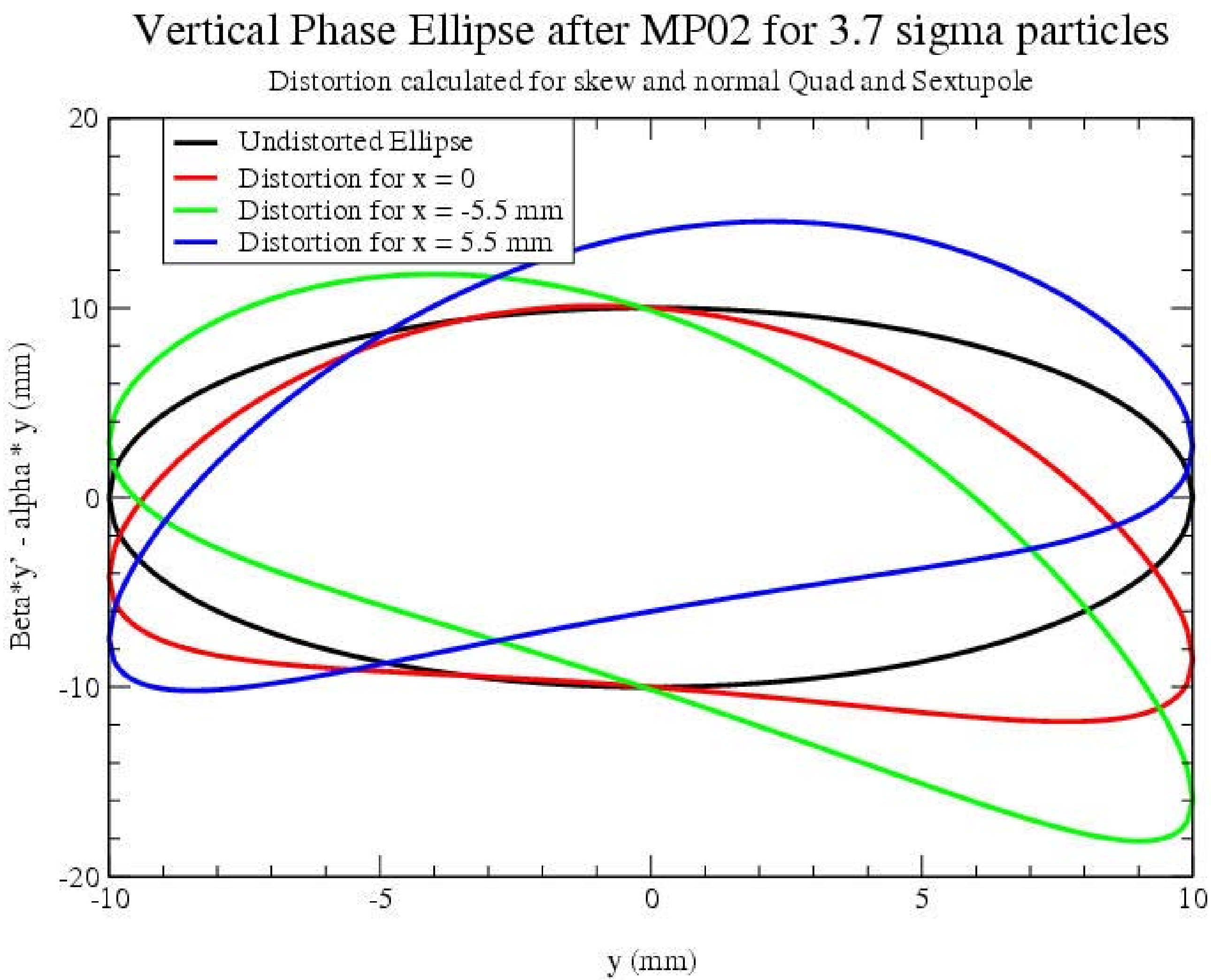
Purpose:

To remove >0.1% of Booster beam in transverse tails which would be lost in Main Injector. This should reduce somewhat the radiation levels in hot spots and the Main Injector and should greatly reduce the number of hot spot, permitting other radiation-inducing problems to be identified and controlled.

Specification:

Massive collimators designed for up to 2% of Booster beam lost without excessive residual radiation. Precision motion control outside of collimators.

MI Radiation Issues and Collimation



MP02 Harmonic
Errors from beam study
M-J Yang
Beams-doc-1573

Distortions
calculated for
three vertical
slices of extreme
Emittance beam
±3.7σ vertically
slices at center
and ±3.7σ radially

MP02 error from
Magnet measurement
somewhat smaller
Beams-doc-462

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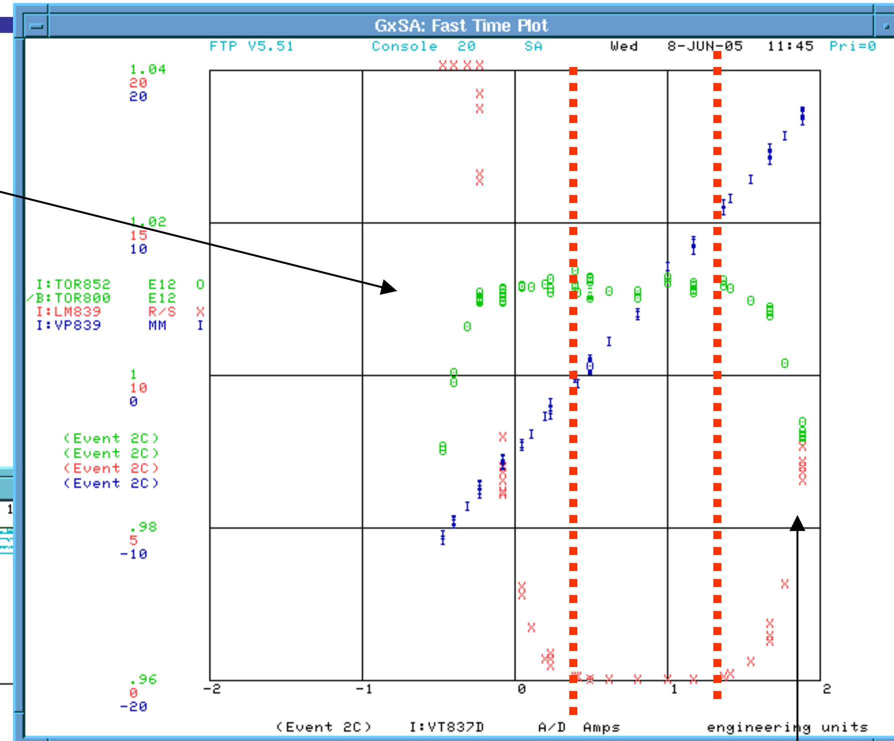
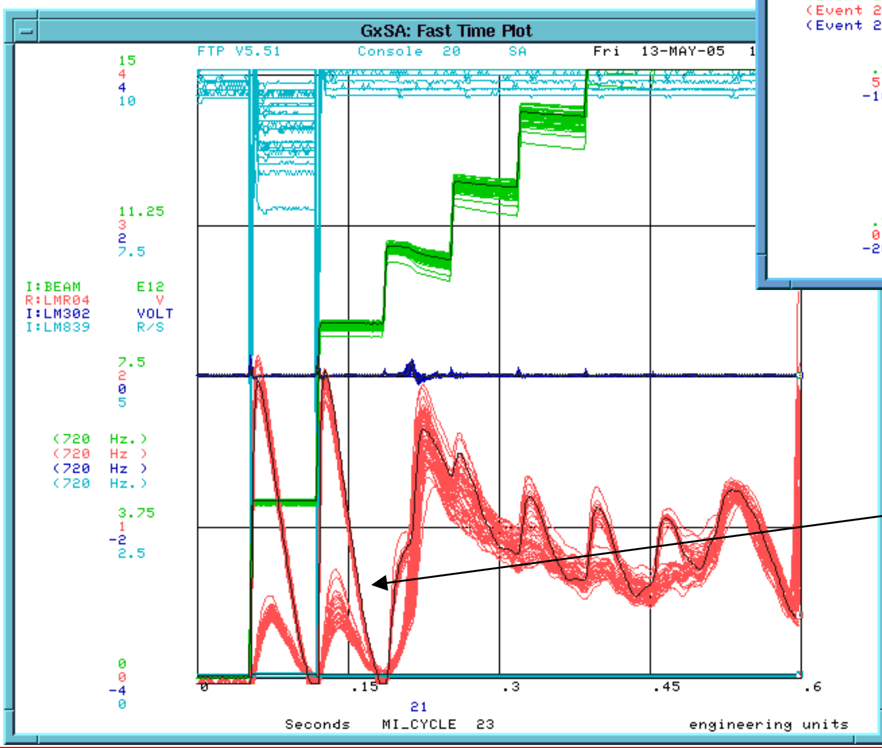
Asymmetric beam distribution at 839



Loss Monitor at ECool



Aperture scan at 839

Scraping level at 839 ~2%

Reduces losses at LMR04

Vertical phase advance from MP02 to 839 is 4.9 x 2π

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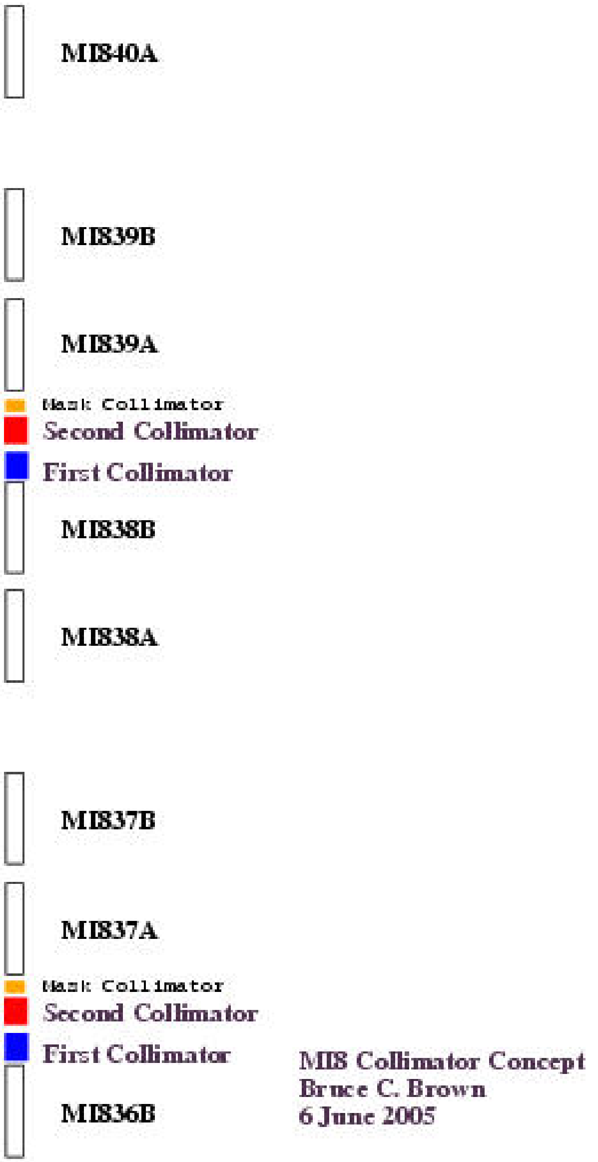
In each region will insert:

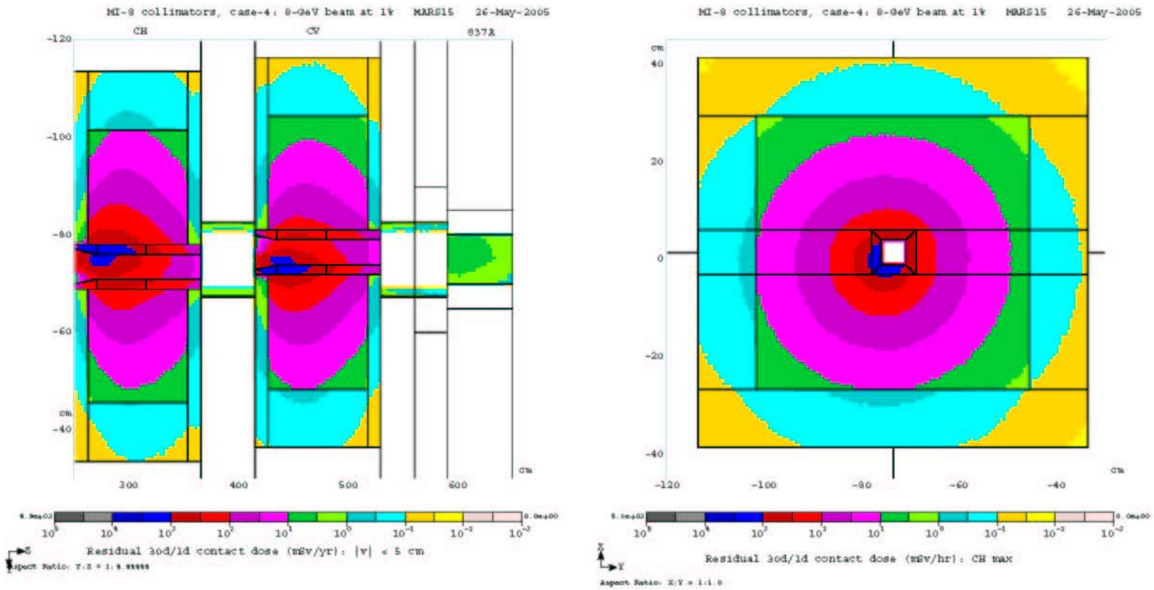
- Vertical BPM
- 45" long collimator
- Bellows
- 45" long collimator
- Loss Monitor
- Fixed mask

Each collimator has
2" x 2" vacuum hole
3.5" x 3.5" Stainless vacuum pipe
20" x 20" x 35" Steel absorber
30" x 30" x 45" Marble shield



Design based on MARS calculations by N. Mokhov

RESIDUAL DOSE IN IRON-MARBLE COLLIMATORS

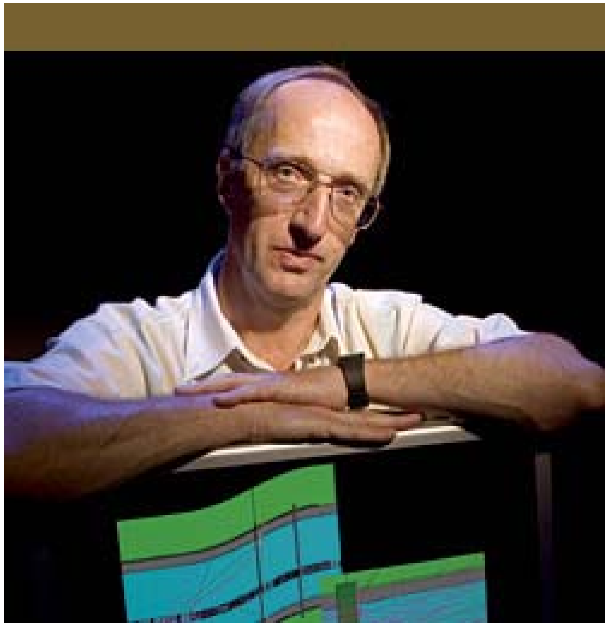


Fermilab

N. Mokhov

From 'symmetry' Magazine Aug 05

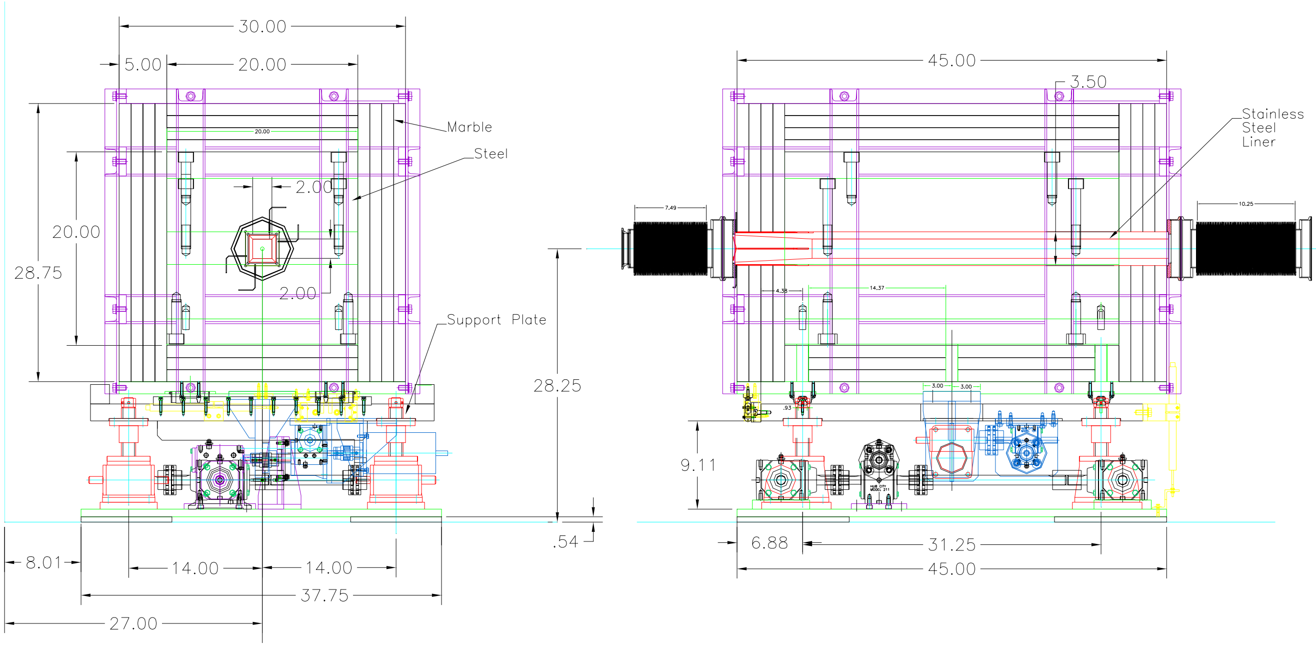
- **Fermilab researcher Nikolai Mokhov is a man in demand.** As accelerator beam energy and intensity increased sharply over the past few decades, the ability to keep excess particles away from detectors became increasingly important. Leading the field of machine-detector interfaces, Mokhov's research is essential for both today's and tomorrow's accelerators. "Almost every group at Fermilab and the LHC has asked for my group's help," Mokhov says. But at the moment, Mokhov is consumed with the calculations, designs, and simulations for the ILC's machine-detector interface.
- For the ILC, Mokhov's realm of expertise begins 1800 meters from the collision point. Here, his interface design begins to strip away the halo of lower-density particles that encase the high-density beam. Without Mokhov's additions, this halo would obscure detector readings and could even damage quadrupole magnets downstream. For the ILC to work properly, it's absolutely critical to reduce the halo by three to four orders of magnitude.
- In computer simulations, this is precisely what Mokhov and his team have accomplished. Mokhov designed a set of metal plates that physically block excess particles, preventing them from continuing toward the collision point where they might interfere with sensitive equipment. By limiting the aperture, these "jaws"—or collimators—will shave off the unneeded particles in the beam halo while allowing the center of the beam to travel on, unimpeded.
- While these jaws should successfully remove the beam halo, their interaction with the excess halo particles will create a spray of muons at intensities 10,000 times higher than the ILC's detectors can handle. To protect the detectors against these muons, Mokhov and his collaborators at Fermilab and SLAC are designing 20-meter-thick steel "spoilers" that seal the entire tunnel with a magnetic field. As muons travel through the spoilers—each weighing tens of kilotons—they will be deflected away from the collision site.
- "This isn't an elegant solution," Mokhov says. "But it does reduce the muon density that reaches the detectors by four orders of magnitude—enough to mitigate the problem."
- Mokhov says that designing collimators and spoilers for the ILC has been especially difficult because of the close proximity of the accelerator components to the detectors. While Fermilab's Tevatron leaves about ten meters between the last accelerator magnet and the detectors, the last accelerator components at the ILC will be inside the detector, only three and a half meters from the collision point. Because an electron beam creates synchrotron photons in a magnetic field, large numbers of these photons will spray directly into the ILC's detector. To avoid this final source of background noise, Mokhov's colleagues designed a second set of collimators and spoilers within the detector to guard against synchrotron photons.
- Mokhov's computer simulations show that his team has successfully limited the excess halo particles, muons, and photons to within acceptable limits. Now Mokhov will focus on achieving better than acceptable results.
- "The trick now is to suppress these particles to as close to zero as possible to limit detector damage," Mokhov says. Working in collaboration with accelerator and detector designers around the world, Mokhov will help ensure that the ILC's precision studies will be possible in the decades to come.



Final Simulation After Snowmass

Mechanical Design for One Collimator

- Motion control for horizontal and vertical motion

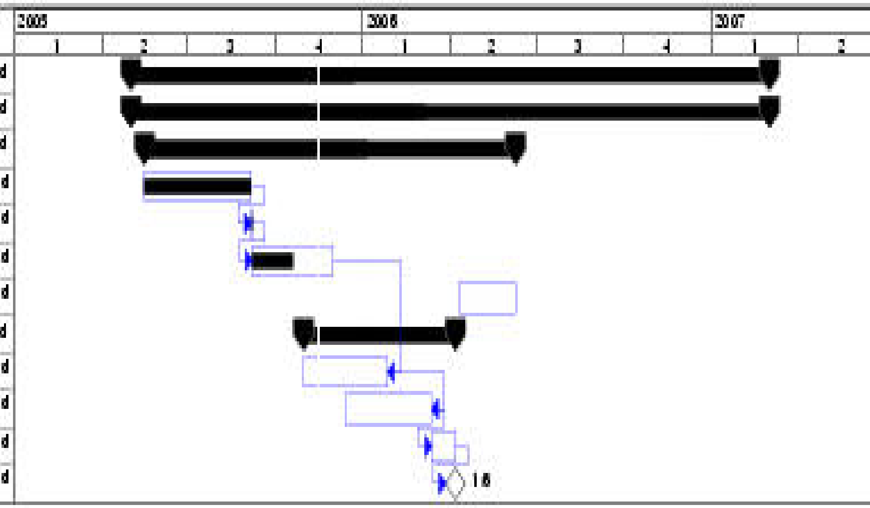


MI Radiation Issues and Collimation

8/16/05

Proton Plan
Collimation Systems
Schedule Information

WBS	Name	St	Fin	%	Float
1.3.2	Collimation Systems	2/1/05	12/1/06	35%	80 d
1.3.2.1	Collimation Systems Design	2/1/05	12/1/06	46%	80 d
1.3.2.1.2	MI-8 Collimation System Design & Commission	2/15/05	3/10/06	60%	285 d
1.3.2.1.2.1	Develop Concept for MI-8 Collimation System	2/15/05	6/6/05	100%	0 d
1.3.2.1.2.2	Review Concept for MI-8 Collimation System	6/7/05	6/7/05	100%	0 d
1.3.2.1.2.3	Design MI-8 Collimation System	6/8/05	8/31/05	50%	3 d
1.3.2.1.2.4	MI-8 Collimation System Commissioning	1/11/06	3/10/06	0%	285 d
1.3.2.2	MI-8 Collimation Syst Procure/Fab/Install	8/1/05	1/6/06	0%	3 d
1.3.2.2.1	Procure MI-8 Collimation System	8/1/05	10/27/05	0%	3 d
1.3.2.2.2	Fabricate MI-8 Collimation System	9/13/05	12/12/05	0%	3 d
1.3.2.2.3	Install MI-8 Collimators	12/13/05	1/6/06	0%	3 d
1.3.2.2.4	MI-8 Collimators Installation Complete	1/6/06	1/6/06	0%	3 d



MI Radiation Issues and Collimation

WBS	Name	Esc SWF	Esc M&S	Cont %
1.3.2	**Collimation Systems**	**$376,015**	**$634,695**	**86%**
1.3.2.1	**Collimation Systems Design**	**$149,997**	**$4,241**	**68%**
1.3.2.1.2	**MI-8 Collimation System Design & Commission**	**$35,114**	**$0**	**45%**
1.3.2.1.2.1	Develop Concept for MI-8 Collimation System	$8,999	$0	**0%**
1.3.2.1.2.2	Review Concept for MI-8 Collimation System	$0	$0	**0%**
1.3.2.1.2.3	Design MI-8 Collimation System	$20,622	$0	**60%**
1.3.2.1.2.4	MI-8 Collimation System Commissioning	$5,492	$0	**60%**
1.3.2.2	**MI-8 Collimation Syst Procure/Fab/Install**	**$29,800**	**$208,974**	**60%**
1.3.2.2.1	Procure MI-8 Collimation System	$1,691	$206,404	**60%**
1.3.2.2.2	Fabricate MI-8 Collimation System	$19,041	$0	**60%**
1.3.2.2.3	Install MI-8 Collimators	$9,068	$2,570	**60%**
1.3.2.2.4	MI-8 Collimators Installation Complete	$0	$0	**0%**

Risk and Risk Mitigation Issues

Orbit Control not Adequate	Set for wider aperture (less collimation) until have auto tune or better power supplies
Schedule	Most motion control items have arrived. Drafting began 15 August.
Assembly Manpower	Try to get design/fabrication in time to avoid manpower crunch.

MI Radiation Issues and Collimation

Summary:

- Main Injector losses have grown – will continue to grow even with improved Booster Beam – we must control residual radiation produced by these losses.
- Plan is being implemented to provide bar-code labeled monitoring location and logging meter to allow monitoring of residual radiation with manageable personnel exposure.
- Improved loss monitor electronics available in 2006 will help maintain adequate knowledge of losses
- Program to measure, simulate and understand Main Injector losses is beginning soon. Expect to design MI collimator system and suitable lattice modifications.

MI Radiation Issues and Collimation

Summary (continued):

Losses currently due to tails of injected Booster beam will create non-trivial residual radiation at proposed operating intensities.

Collimation in the MI8 Line to remove beam tails is specified and design/fabrication is underway.

Cost, schedule and manpower needs are manageable but will continue to require commitment to permit installation and commissioning in FY06.

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